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PICN-MUCN BEAM TRANSPORT SYSTEM
FOR A 600 MEV SYNCHROCYCLOTRON

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Work is being performed on the design of a pion-muon beam transport system in connection with The Space Radiation Effects Laboratory 600 MeV synchrocyclotron. The purpose of this channel is: 1) to trap pions coming from the cyclotron and conduct them through the shielding wall out to the experimental area, 2) to trap muons that have come from the decay of pions within the channel and conduct these decay muons out into the experimental room. Calculations on the design of such a channel have been based on the established description of beam optics by transformations in phase space; the figure of merit of a particular channel system is the amount of phase space area accepted at the cyclotron by an experimental target projected through the channel system.

Two channel systems are under consideration, a superconducting solenoid and a linear array of alternately focussing and defocussing quadrupoles. The superconducting solenoid seems to offer the advantage of accepting at 20 kilogauss approximately four times the phase space area of a quadrupole array (at 10 kilogauss on the pole tip) having the same aperture. However, the present uncertainty in construction of a practical superconducting solenoid of sufficient size has resulted in devoting the main part of the design effort on the quadrupole system.

The work on the beam optics for quadrupole design can be divided into four areas:

- 1) The pion or primary phase space transmitted by an infinitely long quadrupole array. A program "Ellipse" was written to give the phase space area (in the form of an ellipse) transmitted by an infinite channel as a function of the electrical and mechanical properties of the channel (lens length, lens aperture, drift space between adjacent lenses, and magnetic field strength). (For design purposes, a finite channel [25 lenses] is being approximated by an infinite channel [Fronteau and Hornsby, CERN 62-36, Figure 2, see also Section 3]). This

program agrees with the results of a similar program written at the University of Chicago and graciously transmitted to us by Professor Telegdi.

2) Michaelis Plot. This program gives the output phase space for pions generated at an internal cyclotron target and being transmitted through the cyclotron fringing field. This program was written at the University of Chicago and was given to us by Professor Telegdi.

3) Necessary additional lenses, including bending magnets for momentum selection, are needed to match the channel phase area to both the phase area of pions from the cyclotron target and the phase area at the channel output subtended by the experimenter's target assembly. A program, "General Beam Transport", has been written to perform this input and output matching using a finite set of quadrupoles, bending magnets, or drift spaces. Additionally, it gives input and output phase space polygons for given apertures for the elements. It is a general purpose program and has been adopted to a program, "Search", which finds optimum parameters for a two-quadrupole input matching system to the channel. The program, "General Beam Transport", is also being used to test the validity of the infinite channel approximation mentioned in 1).

4) Muon decay inside channel. An adoption, "Muon", of the general secondary beam program of Fronteau (J. Fronteau, CERN 64-11) was written to approximate the muon spectrum from pion decay within the channel. This program assumes the channel is infinite and that its input phase space is completely filled at one momentum.

At the present time the "Muon" program is just getting under way, and the design for a quadrupole system with an aperture of 26 cm and pion momentum of 200 MeV/c is being completed. Input matching has been attained by the use of two additional quadrupoles and output matching by the use of a single quadrupole

followed by a bending magnet for an experimental target approximately 14 x 10 cm at 150-200 MeV/c.

The design for a 20 cm aperture system is partially completed; from intermediate results it appears that matching becomes more difficult than for the 26 cm aperture system.

Several types of quadrupole configurations are being considered. The optimum quadrupole design, both in terms of aberrations and maximum field gradients, is the Blewett design currently being employed at the Brookhaven AGS. Possibly cheaper designs are those of G. Danby (private communication) using a polygonally shaped pole piece, and The University of Chicago (V. Telegdi, High Energy Cyclotron Improvement Conference, February 1964, College of William and Mary) using centrifugal casting for the yoke pieces. The first two designs have small winding cross-sectional area and resulting high power consumption.

We have had the benefit of two consulting trips from Dr. A. Citron of CERN who gave extremely valuable advice on design aspects of the channel. In addition, visits were made with the magnet group at Brookhaven under Dr. G. K. Green and with Dr. F. Shoemaker at Princeton in connection with quadrupole design.

The above work has been performed with the guidance and help of Professor R. T. Siegel and with the assistance of J. Waters and W. Shuler. Dr. John Kane has contributed two months necessary time to the work on this grant.

During the past month and a half a minimal amount of effort has been expended on the design study since most of the work of Drs. Siegel and Funsten has been devoted to main magnet shimming operations on the NASA synchrocyclotron. This work at SREL was necessitated by desirability of having a homogeneous and symmetric main magnetic field in order to permit future increase in external proton beam current.